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The effect of response cost on instrumental performance in higher and lower schizotypal participants

Phil Reed

Swansea University

Correspondence address: Phil Reed,
Department of Psychology,
Swansea University,
Singleton Park,
Swansea, SA2 8PP, UK.
e-mail: p.reed@swansea.ac.uk

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Abstract

This study explored the relationship between response cost and the responding maintained by free-operant schedules of reinforcement for participants with lower and higher levels of schizotypy. The 'discounting' hypothesis suggests that those with higher levels of schizotypy should be less sensitive to the negative consequences of their behavior. This predicts that participants with higher-schizotypy scores would have higher response levels on any given schedule, and that the effect of increasing response cost would not be as noticeable for this group. Participants responded via a computer keyboard on random interval (RI) 30-s, 60-s, and 120-s schedules of reinforcement for points (60 points), and experienced response costs of either low (1-point deduction) or high (10-point deduction) response costs. The UE subscale of the O-LIFE(B) was used to measure schizotypy levels. Response rates were higher with low-costs compared to high-costs for those with higher-UE scores, but not for those with lower-UE scores. That response cost differentially affected higher-UE scorers, suggesting that a 'disconfirmation' view of these data does not explain free-operant performance well.

Keywords: schizotypy; schedules of reinforcement; response cost; disconfirmation; temporal discrimination; threat.

Schizotypy refers to characteristics associated with, but less serious than, the symptoms of schizophrenia (Bentall, Claridge, & Slade, 1989; Claridge, 1990; Claridge & Beech, 1995; Meehl, 1962). People who have high scores on self-reported schizotypy questionnaires are at higher risk of developing schizophrenia-spectrum disorders (Gooding, Tallent & Matts., 2005; Kwapil, 1998; Kwapil, Miller, Zinser, Chapman & Chapman, 1997; Poulton, Caspi, Moffitt, Cannon, Murray, & Harrington, 2000). Those scoring highly on psychometrically-measured scales of schizotypy display characteristic differences in their cognitive abilities, relative to those who score lower on schizotypy scales, and which are similar to those with schizophrenia (e.g., Garety, Kuipers, Fowler, Freeman, & Bebbington, 2001; Tsakanikos & Reed, 2005). These differences also have been taken to impact on a variety of learning abilities (e.g., Randell, Kumar, Gupta, & Reed, 2009; Tsakanikos, 2004).

Research using non-clinical populations has found that schedules of reinforcement are an effective way to study learning in individuals (Reed, 2001). Using the O-LIFE(B) schizotypy questionnaire (Mason, Linney, & Claridge, 2005), individuals scoring lower on the Unusual Experiences (UE) subscale (related to positive symptoms of schizophrenia), display higher levels of responding on random-ratio reinforcement (RR) schedules – where reinforcement is related directly to the number of responses emitted – compared to their level of responding on random-interval reinforcement (RI) schedules (Randell, Ranjith-Kumar, Gupta, & Reed, 2009). This is a typical pattern of response rate difference across these two schedules (Ferster & Skinner, 1957; Reed, 2001; 2015). However, individuals scoring higher on the UE subscale show no reliable differences between the response rates on RR and RI schedules, suggesting that they are unable to make a strong distinction between the two schedules, and differ from those with lower UE scores (Randell, May, Jones, & Reed, 2011).

Several theories regarding the differences in processing related to UE can be employed in an attempt to explain response-differences seen across reinforcement schedules in people with lower and higher levels of schizotypy. One explanation is that patients with schizophrenia suffer from impaired temporal discrimination (Carroll, Boggs, O'Donnell, Shekhar, & Hetrick, 2008; Locke, 1974; Tysk, 1983), which also is present for those with higher-UE schizotypy scores, and who tend to underestimate the passage of time (Reed & Randell, 2014). As RI schedules involve a temporal component that modulates performance, with shorter intervals producing higher rates of responding (Davison & McCarthy, 2016; Herrnstein, 1970), such a timing deficit could affect performance on RI schedules of reinforcement, with over-responding been predicted in higher compared to lower UE scorers (Randell et al., 2011). This would tend to decrease the response rate differential between RR and RI schedules for high UE scorers, thus, explaining why high UE scorers display less of a response-rate distinction between RR and RI schedules (Randell et al., 2011).

However, an alternative explanation is that higher-UE scorers, like deluded patients, suffer from a 'disconfirmation deficit' (Garety, Hemsley & Wessely, 1991; Hemsley & Garety, 1986; Linney, Peters & Ayton, 1998). This may be a result of the non-reinforced responses emitted on RI schedules having a different effect on rates of responding for higher-UE scorers compared to lower-UE scorers. If this is the case, then higher-UE scorers may be less sensitive to the number of responses emitted and not reinforced on RI schedules, relative to lower-UE scorers. This may lead the former group to over-respond on RI schedules, and to reduce the typical RR-RI pattern of responding.

One possible test of these views is to examine the effect of response cost on such schedules. Such a manipulation has been shown to reduce rates of responding to schedules of reinforcement in humans (Reed, Smale, Owens, & Freegard, 2018), but might be expected to do so to a lesser extent for those with higher-UE scores, if the disconfirmation deficit view is a good explanation for instrumental responding maintained by free-operant schedules. In contrast, the temporal discrimination view would suggest similar impact of this manipulation across all levels of schoztypy.

However, multiple studies have demonstrated that those with schizophrenia-spectrum disorders show attentional biases towards threat-related stimuli (Bentall, Kaney, & Bowen-Jones, 1995; Blackwood, Howard, Bentall, & Murray, 2001; Green, Williams & Davidson, 2001; Saunders, Vallath, & Reed, 2015). More specifically, those with paranoid symptoms, as are measures by the UE subscale of the O-LIFE, are especially prone to interference from threat-related stimuli (Bentall & Kaney, 1989; Epstein, Stern, & Silbersweig, 1999; Leafhead, Young & Szulecka, 1996; Saunders et al., 2014). If this were the case for those with higher-UE scores, then it might be expected that response cost would have a greater impact on their rats of responding on schedules of reinforcement.

Thus, the current study aimed to examine the relationship between schizotypy levels and responding on free-operant schedules in order to test between these potential explanations. To this end, the effect of UE scores on performance, across a range of RI schedules, with lower and higher response costs, was examined. If previous schedule differences between lower- and higher-scoring UE participants were due to a temporal discrimination problem, then those with lower-UE scores should differentiate between the schedules more easily in terms of their performance, than those with higher UE scores. There should be a negligible effect of response cost depending on schiziotypy. In contrast, if schedule differences are due to a ‘disconfirmation’ problem, then those with a higher-UE score should not show such a differentiation, and should be less affected by response cost than those with a lower-UE score. Finally, if performance were most-impacted by an over-sensitivity to threat-related stimuli, then it might be expected that response cost would be more impactful for higher- compared to lower-scoring UE individuals.

Method

Participants

Sixty undergraduate students (14 male, 46 female), with a mean age of 26 (± 13.6 SD; range = 18 – 32) years were recruited through the Psychology Department subject-pool system. No participant self-reported a history of psychiatric illness. Ethical permission for the study was given by the University's Psychology Department Ethics Committee.

Materials

Oxford Liverpool Inventory of Feelings and Experience – Brief (O-LIFE(B); Mason, Claridge, & Jackson, 1995) is a self-report measure of schizotypy, using 43 questions, divided into four sub-scales: Unusual Experiences (UE; cognitive distortions and unusual perceptual thinking or experiences); Cognitive Disorganization (CD; difficulties with decision making and little attention span); Introverted Anhedonia (IA; very little enjoyment or excitement in social situations); and Impulsive Nonconformity (IN; behavior of a violent, reckless, or impulsive nature). The scale has established its validity and reliability, and has an internal reliability Cronbach α between 0.72 and 0.89 (Mason & Claridge, 2006; Cella, Taylor & Reed, 2007). Given that previously the most reliable and consistent findings in terms of response rate were found with regard to the UE subscale of the OLIFE-B (Randell et al., 2011), only this subscale was considered. The Cronbach α for the UE subscale for the current sample was 0.81.

Experimental Task: The experimental task was presented using Visual Basic (6.0) on a laptop computer with a 15.6-inch screen. The program presented an RI schedule (30s, 60s, or 120s) to the participants. On a particular schedule, each second had an equal probability of being assigned as the period after which reinforcement would be delivered for a response (i.e., 1/30, 1/60, or 1/120). Each participant began the experiment with 40 points, displayed in a box, under the word "points", in the middle of the screen horizontally, approximately one third of the way from the bottom of the screen. A colored square (either blue, purple, or yellow), approximately 8cm wide x 3cm high, was displayed in the middle of the screen, approximately one third from the top of the screen. Reinforcement consisted of 60 points being added to the 'points' box. Each response subtracted either 1 point or 10 points, depending on group assignment, from the 'points' box. This task was adapted from that reported by Reed (2015).

Procedure

Participants were tested individually in a quiet room containing a desk, a chair, and a computer. Participants were presented with the following instructions on the computer screen:

"*Your task is to score as many points as possible by pressing the space bar. There will be three tasks. The shape that changes colour between the tasks is important. Sometimes you might need to press quickly, and sometimes you might need to press slowly. Click to proceed.*"

The participants received these instructions as such instructions have been used in previous studies of human schedule performance, and have been shown to be effective for inducing schedule behavior in humans that resembles that in nonhumans (see Bradshaw & Reed, 2012; Reed, 2015b). After presentation of the instructions, each participant was exposed to all three schedule-types (RI-30s, RI-60s, and RI-120s) – in a randomized order across participants. Each schedule was presented once to each participant, each schedule exposure lasted 8 min, and there was a 30s inter component interval. Each different schedule was signaled by the presence of the different colored rectangle on the screen. The particular colors used to signal the schedules were randomized. Each response subtracted one point from the 'points' box displayed on the screen (responding was possible even with a negative points total). Reinforcement consisted of the addition of 60 points to the 'points' box. Following this, the participants completed the O-LIFE(B) scale.

Results

Participants were divided into high and low scoring groups, according to a mean split, for the UE subscale of the O-LIFE(B). Thirty-two participants were grouped in the lower-scoring UE group (mean = 1.22 $\pm$ 0.69; range 0 – 2), and 28 participants were grouped in the higher-scoring UE group (mean UE = 5.04 $\pm$ 2.28; range = 3 – 11). A mean split was used, as opposed to a regression analysis, due to the sample size, to maintain consistency with previous studies in this area (Randell et al., 2011; Saunders et al., 2015), and also because it is unclear whether or not any relationship between UE and response rates would be linear, or a step function. A group design is neutral with regard to this issue, but a regression analysis assumes a linear relationship, which is not certain to be obtained between psychometric functions and performance (see Osborne, McHugh, Saunders, & Reed, 2008).

Figure 1 about here

Figure 1 shows the group-mean number of responses made by both high and low UE scoring participants for each of the schedule conditions for both the low and high response cost groups. Inspection of these data shows that the differentiation between the schedules improved for the lower-scoring UE groups as the response cost increased; with responding being more related to the programmed rate of reinforcement. Responding in this group was also numerically lower for the higher response-cost compared to the lower response-cost. The higher-scoring UE group also showed differentiation between the schedules at the low cost condition, and their rates of responding were impacted to a much greater extent by response cost; their responding was suppressed to a much greater extent than the lower-UE scoring groups in the high-cost condition.

A three-factor mixed-model analysis of variance (ANOVA) with UE (lower versus higher) and response cost (low versus high) as between-subject factors, and schedule type (30s v 60s x 120s) as a within-subject factor, was conducted on these data. The appropriate Bayes statistic for each result are also reported. This analysis revealed significant main effects of schedule, $F(2,112) = 3.05$, $p = .033$, $\eta^2_p = .059$[95% CI: .000-.138], $pH_1/D = .906$, and response cost, $F(1,56) = 6.83$, $p = .011$, $\eta^2_p = .109$[.006-.269], $pH_1/D = .803$, but not of UE, $F < 1$, $p = .588$, $\eta^2_p = .005$[.000-.091], $pH_0/D = .868$. There was a significant interaction between response cost and UE, $F(1,56) = 3.81$, $p = .043$, $\eta^2_p = .063$[.000-.211], $pH_1/D = .542$, but not between response cost and schedule, $F(2,112) = 1.36$, $p = .262$, $\eta^2_p = .024$[.000-.092], $pH_0/D = .996$, UE and schedule, $F(2,112) = 1.04$, $p = .357$, $\eta^2_p = .018$[.000-.080], $pH_0/D = .971$, nor between all three factors, $F(2,112) = 1.01$, $p = .367$, $\eta^2_p = .018$[.000-.079] $pH_0/D = .972$.

Simple effect analyses were conducted on the mean number of responses emitted across the three schedule conditions comparing the lower- and higher-scoring UE groups at the low cost condition, which revealed a significantly higher number of responses for the higher-UE group, $F(1,112) = 25.89$, $p < .001$, $\eta^2_p = .188$[.074-.310], $pH_1/D = .878$. However, there was no difference between the UE groups at the high cost condition, $F(1,112) = 2.52$, $p = .120$, $\eta^2_p = .022$[.000-.100], $pH_0/D = .791$. There was no difference between the low and high response cost conditions for the lower-UE group, $F < 1$, $\eta^2_p = .002$[.000-.048], $pH_0/D = .961$, but the high-cost condition produced lower levels of responding than the lower-cost condition for the higher-UE group, $F(1,112) = 8.08$, $p = .005$, $\eta^2_p = .067$[.006-.170], $pH_1/D = .787$.

Discussion

The present study explored the effect of response cost and RI schedule type for lower- and higher-scoring UE schizotypal participants, to test between a number of theoretical accounts of such performance. The results demonstrated that, as the density of reinforcement decreased, rates of responding typically decreased. This reflects the expected effect of decreasing the rate of reinforcement on responding (Davison & McCarthy, 2016; Herrnstein, 1970). However, higher-UE scorers were more impacted by the response cost manipulation than lower-UE scorers. This was the product of the higher-UE scorers emitting more responses than the lower-UE scorers at the low-cost condition, but there being no difference between the UE groups at the high cost condition.

The current results offer no support for the ‘disconfirmation’ theory (e.g., Garety et al., 1991) as applied to instrumental responding maintained by schedules of reinforcement. This view would suggest two patterns of data – that there would be less differentiation between the schedules for the higher- compared to the lower-scoring UE group, and that the higher-scoring UE group would be less impacted by the addition of a response cost. It was apparent that neither of these effects were noted strongly in the current data. Although higher-scoring UE participants did tend to over-respond on the schedules relative to the lower-scoring UE participants for the low-cost condition, which would be expected according to this view, this pattern of data was not noted with the high cost condition – indeed the reverse pattern of performance was noted. Of course, these conclusions do rely on non-significant results, and need to be treated with caution, but the fact that the numerical pattern of data was the reverse of that predicted, and the Baysian analyses also supports these conclusions, suggests gives some weight may be placed on this interpretation.

The current data offer only partial support for a temporal discrimination view (Randell et al., 2011) of these data. This view would suggest that the lower-scoring UE participants would show better differentiation between the schedules than the higher-scoring UE participants. Numerically, the lower-scoring participants did differentiate between the schedules in the expected manner – reducing their responding as the rate of reinforcement decreased. However, although this difference between the UE groups was pronounced at the high-cost condition, consideration of the low-cost condition shows that the differentiation was better in the higher-scoring UE groups.

In contrast, the view that suggests threat stimuli impact those with higher-UE more than lower-UE does help to explain this pattern of data. Those with higher-scoring-UE were much more impacted by the response-cost increase than those with lower-scoring UE, and the increase in response cost served to suppress responding across all schedules for the former group. Threat stimuli can produce a negative affect in people, which, in the schizophrenia spectrum, has been shown to influence functions like attention, perception, response and language (Burbridge & Barch, 2002; Docherty, Evans, Sledge, Seibyl, & Krystal, 1994; Kerns & Berenbaum, 2000). It has been found that negative affect can be caused by something perceived as negative, or as a threat, during an experimental task, or by disrupted family environments or traumatic life-events in a real-life situation (Docherty & Herbert, 1997; Malla & Norman, 1992; Saunders et al., 2015; Slade, 1972).

There are a number of limitations to the current study that should be noted. The sample was relatively small, and based on an undergraduate population. Further research with a larger sample, and greater range of schizotypal personality scores, would be useful to extend these findings. The small sample also makes difficult interpretation of non-significant results, which should be treated with caution, although these conclusions are also supported by examination of the appropriate Bayes statistics.

To summarize, the present study found support for the theory that threat stimuli can explain some aspects of responding on schedules of reinforcement, and it showed that response cost had a greater affect on responding for people with high levels of schizotypy than those with lower levels of schizotypy, which is at odds with the ‘disconfirmation’ view.

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Figure 1: Group-mean number of responses emitted in each schedule condition for the lower and higher response costs and lower and higher UE scores (error bars = 95% confidence limits).